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REVIEW ARTICLE

Miniscrew implant applications in contemporary orthodontics

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Abstract The need for orthodontic treatment modalities that provide maximal anchorage control but with minimal patient compliance requirements has led to the development of implant-assisted orthodontics and dentofacial orthopedics. Skeletal anchorage with miniscrew implants has no patient compliance requirements and has been widely incorporated in orthodontic practice. Miniscrew implants are now routinely used as anchorage devices in orthodontic treatment. This review summarizes recent data regarding the interpretation of bone data (i.e., bone quantity and quality) obtained by preoperative diagnostic computed tomography (CT) or by cone-beam computed tomography (CBCT) prior to miniscrew implant placement. Such data are essential when selecting appropriate sites for miniscrew implant placement. Bone characteristics that are indications and contraindications for treatment with miniscrew implants are discussed. Additionally, bicortical orthodontic skeletal anchorage, risks associated with miniscrew implant failure, and miniscrew implants for nonsurgical correction of occlusal cant or vertical excess are reviewed. Finally, implant stability is compared between titanium alloy and stainless steel miniscrew implants.

Conflicts of interest: The authors report no conflicts of interest. The authors alone are responsible for the content and writing of this paper.

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Introduction

Ensuring adequate anchorage is often challenging in orthodontics and dentofacial orthopedics [1], especially because many of the various methods developed for reinforcing anchorage depend on patient compliance. A major advance in orthodontic treatment in recent years is the introduction of skeletal anchorage with miniscrew implants, which is widely used in orthodontic treatments for expanding the boundary of tooth movement and has no patient compliance requirements [2]. Miniscrew implants are now well-established auxiliary anchorage devices and are routinely used in orthodontic practice.

Orthodontic miniscrew implants

The need for orthodontic treatment modalities that maximize anchorage control and minimize patient compliance requirements has led to the development of implant-assisted orthodontics. Although osseo-integrated dental implants provide reliable anchorage for managing malocclusions [3], their applications are limited by their large size. The miniplate has greater stability compared to the miniscrew, but the flap surgery required for insertion and removal results in swelling and discomfort [4]. Miniscrew implants are now the most common temporary anchorage devices because of their many advantages, including their low cost and simple surgical placement and removal. The small and convenient size of the miniscrew implant also enables their use in many anatomical regions, including the interdental area [5].

Bone quantity and quality

Cortical bone thickness is an important factor in the success of a miniscrew implant. Insufficient cortical bone thickness often causes inadequate primary stability. If primary stability is not achieved upon insertion, the miniscrew implant may loosen during orthodontic treatment [6]. A cortical bone thickness of less than 1 mm has a higher likelihood of miniscrew implant failure compared to a thickness of 1 mm or more [7,8]. Numerical analyses using finite element models (FEMs) have shown that deflection of miniscrew implants decreases as cortical bone thickness increases [9] and that cortical bone with thickness less than 1 mm is vulnerable to stresses that can cause bone resorption in this region [10].

Two key determinants of primary stability are bone quality and quantity [11]. Cortical bone quantity and quality affect the long-term stability of a miniscrew implant. Stationary anchorage failure often results from low bone density due to inadequate cortical thickness [12]. The primary implant stability of a miniscrew implant can be estimated by computed tomography (CT) measurements of cortical bone thickness [13].

Use of CT or CBCT for preoperative evaluation of miniscrew implant placement

Because they provide clinicians with potentially important information, CT or cone-beam computed tomography (CBCT) imaging should ideally be performed in all orthodontic patients who are candidates for miniscrew implants. Routine panoramic, lateral, and frontal cephalometric radiographs may not provide all information needed to optimize the location of a miniscrew placement. However, lateral cephalometric radiographs enable accurate and reliable preoperative evaluations of bone quantity in the paramedian palate and palatal region [14,15]. The bone quality in these regions tends to be relatively high [16].

Sites for miniscrew implant placement

Miniscrew implants are available in varying lengths and diameters to accommodate placement at different sites in both jaws. Most miniscrew implants have a thread diameter ranging from 1.2 mm to 2.0 mm and a length ranging from 6.0 mm to 12.0 mm. Potential sites for miniscrew implant placement in the maxilla include the area below the anterior nasal spine, the palate (either on the midpalate or the paramedian palate), the infrazygomatic crest, the maxillary tuberosities, and the alveolar process (both buccally and palatally between the roots of the teeth). Possible sites for miniscrew implant placement in the mandible include the symphysis or parasymphysis, the alveolar process (between the roots of the teeth), and the retromolar area [17,18].

Indications and contraindications for treatment with miniscrew implants

The most common indication for treatment with miniscrew implants is molar protraction followed by indirect anchorage for space closure, intrusion of supraerupted teeth, intrusion of anterior open bite, anterior en-masse retraction, molar uprighting, intrusion of maxillary cant, molar distalization, traction on impacted canine, and attachment of protraction facemask. Other indications occur in a clear minority of cases [19].

Contraindications for using miniscrew implants include problematic healing, compromised immune defense, bleeding disorders, pathological bone quality, or inadequate oral hygiene [4,20]. Miniscrew implants may also be contraindicated in children with deciduous or early mixed dentition [20]. Heavy smoking detrimentally affects the success rates of orthodontic miniscrews [21]. The contributing role of temporary smoking cessation in the success of dental implants [22] should be considered in the prognosis of orthodontic miniscrew placements but requires further investigation.

Bicortical orthodontic skeletal anchorage

Compared to monocortical miniscrew placement, bicortical placement provides higher force resistance and stability but lower cortical bone stress [23]. Because the miniscrew implant is inserted across the full width of the alveolus, most of the critical orthodontic anchorage is provided by the buccal/labial layer and lingual cortical bone layer [24]. The clinically relevant dimensions of bone available for a palatal miniscrew implant anchorage include both cortical layers, i.e., the outer cortical layer of the nasal floor and the outer cortical layer of the oral hard palate [15]. Clinicians should consider bicortical skeletal anchorage when increased orthodontic loading or diminished cortical bone thickness is expected.

Risk factors associated with failure of miniscrew implants

A recent meta-analysis reported that miniscrew implants have a failure rate of 0.123 (87.7% success rate) [25]. This figure is slightly higher than the 83.6% success rate reported in a previous meta-analysis of uncontrolled studies [26]. Compared to other treatments, miniscrew implants have a relatively low and clinical acceptable failure rate, which explains their widespread use in clinical practice. The clinical success rate of miniscrew implants currently used in implant-assisted orthodontics exceeds 80%, which is a considerable improvement compared to previous miniscrew implants but still unsatisfactory, especially in comparison with the success rate for dental implants (>90%) [27,28].

The failure rate of the miniscrew implants does not significantly differ by sex, insertion site, or insertion side (left vs. right) [7,29]. However, failure risks tend to be higher in younger (<20 years old) patients compared to older (>20 years old) patients [4,7], probably due to the active bone metabolism and low maturation of the maxillofacial bone in growing children [7].

The failure rates of miniscrew implants inserted in the mandible tend to be higher than those inserted in the maxilla. The difference is attributable to: (1) the higher bone density of the mandible, which requires a higher insertion torque that decreases the survivability of the miniscrew implant [30] and overheats the mandible during the placement procedure [4]; and (2) the smaller amount of cortical bone formation at the head of the miniscrew implants inserted in the mandible [31].

Insertion torque is positively associated with miniscrew implant failure rates, and insertion torque values higher than 10 Ncm are associated with a higher failure rate compared to values lower than 10 Ncm [7,32]. A miniscrew implant failure may result from excess stress at the initial bone—implant interface resulting in microdamage, local ischemia, and delayed healing in the adjacent bone [32].

The proximity of a miniscrew implant to the adjacent tooth root is a major cause of failure, particularly in the mandible [33]. Another contributing factor in miniscrew implant failure is root contact during insertion [33,34]. However, root injuries are usually treatable. Removal of the mobile screws that cause inflammation can prevent further root resorption of the adjacent tooth [34,35]. Finite element analysis (FEM) is useful for simulating stress distribution in orthodontic biomechanics. Numerical analyses using FEMs have shown that root contact increases stresses that can cause irreversible loss of miniscrew implant stability [10,36].

Attached gingiva is not always necessary for miniscrew implant maintenance but is more favorable compared with the oral mucosa [2]. However, irritation of the miniscrew installation site by oral mucosa may cause unfavorable conditions, including compromised stability. Therefore, the insertion site must be carefully selected to minimize potential soft-tissue irritation or inflammation; firm attached gingiva is usually preferable to movable mucosa [29].

Relative stability of titanium alloy and stainless steel miniscrew implants

Despite their many differences, both titanium alloy and stainless steel meet the mechanical requirements for stable miniscrew implants. The primary stability of a miniscrew implant depends on insertion depth rather than on the implant material [37]. Selecting the appropriate depth is extremely important for primary stability of the miniscrew implant and is critical for treatment success. Although titanium-alloy miniscrews achieve stationary anchorage mainly through mechanical retention, they can achieve partial osseointegration after 3 weeks. The partial osseointegration of titanium-alloy miniscrew implants is a distinct advantage in orthodontic applications because it provides effective anchorage with easy insertion and removal [1]. However, partial osseointegration can also complicate the removal of titanium-alloy miniscrew implants by increasing the torque values required for removal. Again, further studies are needed to compare the long-term stability between orthodontic miniscrew implants composed of titanium alloy and those composed of stainless steel.

Miniscrew implant for nonsurgical correction of occlusal cant or vertical excess

The mechanics of using miniscrew implants follow general biomechanical principles. However, compared with conventional orthodontic principles, miniscrew implants have several characteristic features that not only make treatment with conventional orthodontic mechanotherapy easier and more efficient, but also enable treatment in which conventional anchorage would be impossible.

Clinical applications of miniscrew implants have been expanded to include correction of occlusal cant and correction of vertical excess that would otherwise require orthognathic surgery. The authors have used miniscrew implant anchorages for vertical control of both left and right side molars in such patients for horizontal and/or vertical improvement in the occlusal cant or vertical skeletal discrepancies.

In adult patients with moderate-to-severe facial asymmetry or hyperdivergency, a combined treatment of orthognathic surgery and orthodontic therapy can improve facial esthetics, and morphological and functional occlusions. In some patients with facial asymmetry or hyperdivergency, miniscrew implant anchorages are a potential alternative to surgery for improving dental and skeletal disharmony in transverse and/or vertical dimensions [38,39] (Fig. 1).

Future directions

The use of orthodontic miniscrew implants expands the envelope of discrepancies that are potentially correctable by orthodontic and dentofacial orthopedic treatment. However, the relative effectiveness and efficiency of

Figure 1. An adult Class III malocclusion with lateral deviation of the mandible (B) resulted in facial asymmetry (A). The posteroanterior cephalometric radiograph detected no cant of the maxilla. However, an occlusal cant (C) and a chin point deviation to the right side from the facial midline (A) were noted. The buccally inclined right maxillary posterior teeth were corrected with elastomeric chains from an orthodontic miniscrew inserted in the midpalate (D). The maxilla was treated without surgery. Modified intraoral vertical ramus osteotomy was performed to correct a lateral deviation in the prognathic mandible after the presurgical orthodontic treatment (E, F).

miniscrew implants used for various clinical problems need further evaluation in prospective controlled studies.

Of the many hypothesized factors in the failure rates of orthodontic miniscrew implants, most need further evidence to support their associations. Clearly, however, the success rate of miniscrew implant placements is improved by CT or CBCT examinations of the dentomaxillofacial field and by technical improvements in the miniscrew implant placement procedure.

Further technical advances in miniscrew implants for skeletal anchorage will require improved understanding of the associated orofacial biology and implant-assisted orthodontic biomechanics.

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